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HAZARDOUS WASTE TREATMENT RESEARCH--

U. S. ENVIRONMENTAL PROTECTION AGENCY

by

Clyde J. Dial
Director
Alternative Technologies Division
Hazardous Waste Engineering Research Laboratory
U. S. Environmental Protection Agency
Cincinnati, Ohio 45268

HAZARDOUS WASTE ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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16. ABSTRACT

Treatment and thermal destruction are becoming the most viable methods for disposing of hazardous wastes. Wastes can be destroyed through a variety of treatment methods and in incinerators, boilers, kilns, and other high temperature industrial processes. The destruction of these materials is regulated under the Resource Conservation and Recovery Act as amended. The Office of Research and Development of the U. S. Environmental Protection Agency conducts research to help establish and technically defend regulations governing the destruction of hazardous materials. The program is conducted at EPA-owned facilities and by Agency contractors. It is highly coordinated with other researchers. These programs will result in regulation, permitting, and compliance actions by the Agency to ensure continued, reliable operation of such facilities and the public acceptance of the location and operation of these facilities.

A description of the EPA research programs and how they interact with private sector industry is provided.

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The Alternative Technology Division's research program provides technical support to the regulatory offices of the Agency. The recent amendments to the Resource Conservation and Recovery Act require, within 66 months, that EPA either ban the disposal of hazardous waste to the land or determine that certain wastes are acceptable for land disposal. To do this, information is needed on which treatment processes exist, what wastes can be handled by the processes, residuals or environmental discharges that are produced by the processes, and the treatment process costs. In implementing this program for the Agency, existing treatment processes and those which are emerging but not yet commercialized are to be examined. As the research program progresses, the information obtained will be transferred to our Regional Offices, State and local agencies, and to the regulated community. Our program to examine existing treatment includes biological, chemical, physical and thermal destruction processes. The thermal portion of this program is long established whereas the "treatment" of hazardous waste research is just beginning.

Hazardous Waste Treatment Research Program

The major objectives of our treatment research program are:

- To provide performance evaluations of alternative hazardous waste treatment systems to allow the OSW to direct that these systems be used, instead of or as pretreatment before land disposal, for selected hazardous waste streams. These evaluations, combined with existing industrial and hazardous waste treatment knowledge, will form the basis for hazardous waste treatment standards to be promulgated under RCRA;

- To identify and document situations in industry in which changes in process or waste management technologies have led to improved waste management practices;

- To provide technology capable of cost effective cleanup of Superfund sites;

- To compile and disseminate technical resource documents and other information to encourage the adoption of environmentally-preferable technologies; and

- To assure the demonstration of promising alternative hazardous waste treatment technologies so that these technologies may be recommended to and utilized by regulatory and industrial organizations.

To accomplish these objectives, we are conducting research on both existing and emerging treatment technologies. In the existing treatment program, four major areas are planned--performance evaluations, case studies, technical resource documents, and demonstrations.

Technical Approach--Existing Treatment

This program will conduct pilot scale or field tests to obtain data on a matrix of waste types and technologies. The specific waste types identified for priority action include: dioxin-bearing wastes, solvents, cyanides,

metals, and halogenated organics. The treatment processes to be evaluated first will include component separation (e.g., carbon adsorption distillation, extraction), phase separation, neutralization, chemical oxidation, incineration, and biological treatment. We expect this program to take several years to complete. Specific tasks planned for implementing this program include establishing criteria for acceptable waste treatment. The treatment method of choice for many types of wastes will be one in which the resulting residuals exhibit characteristics of incinerator ash in terms of organic content and leachability. Our efforts will include the characterization of incinerator residues to assist in establishing this criteria.

We will be assessing the performance of a variety of treatment systems through bench-scale, pilot-scale, and field tests. Included in these tests will be the testing of EPA's existing mobile pilot treatment systems in co-operation with industry. Case studies of industrial practices which have been successful in treating hazardous wastes will be documented. All of this work will be summarized in technical resource documents which will be provided to the user community and presented at our annual research symposium held in Cincinnati each Spring.

A demonstration program to advance the state of hazardous waste treatment technology will be conducted. We plan to work with State governments in this program, for we believe having them as partners will improve our ability to access operating facilities that can incorporate these treatment technologies. Our aim is to identify and demonstrate the processes and approaches that represent clear advantages over land disposal.

Technical Approach--Emerging Treatment

That segment of our treatment research program examining emerging technologies takes a different slant in approach. We are concentrating on a number of problem areas as follows:

- Dilute aqueous wastes--these are likely to be the first to be banned from landfills;
- Sludges containing heavy metals--toxicity is of major concern to EPA, but land disposal of potentially scarce metals constitutes a waste of valuable resources;
- Soil contamination by leaks, spills, or misapplication of hazardous materials such as pesticides--the Missouri dioxin problem is a good example;
- Sediments in harbors or waterways--the Waukegan and New Bedford harbors and Hudson River PCB sediments are examples; and
- Leachate from poorly constructed or disturbed landfills.

In examining solutions to those problems, we have structured our program primarily to investigate chemical and biological detoxification methods.

Biological Detoxification Research Program

This program is focusing on developing organisms or substances produced by organisms that can destroy specific pollutants or compounds. The work has centered on dealing with the destruction of contaminants, especially dioxins, contained in soils. We are working with a variety of biological organisms, bacteria, fungi, yeasts, and higher plants such as milkweed.

One characteristic of the program that has somewhat surprised us is the speed at which progress is being made. In several cases, our research appears to be to the point where we have successfully developed an organism to detoxify or destroy specific pollutants. This will lead us to a decision point in our research that has two facets. The first is the problem of taking these laboratory-designed organisms and successfully getting them to survive in a real-world environmental situation. Parallel with that is the second quasi-legal problem of having an established protocol and legal capability of taking these organisms from the laboratory and placing them into the environment. The latter is being worked on by others, and we believe the necessary protocols for doing this will be in place for our use.

One of the more successful projects that we have to date is a project in which white rot fungus is being investigated and appears to destroy all compounds that have been investigated to date, including 2,3,7,8-chlorinated dioxin.

We have not worked with any anerobic organisms to date and believe that this is an important aspect of future research. We are also, by choice, not working with the pollutant problems from industries that use gene-engineered organisms in their production processes. This research is the activity of other segments of our research organization.

Chemical Detoxification Research Program

Historically, this program focused on solving contaminated soil pollution problems. This work is centered on the dioxin problem in Missouri. We have worked primarily on the development of a series of chemical reagents using polyethylene glycol and metals or metal hydroxides. Over several years, the APEG reagent has evolved to one consisting of potassium hydroxide and PEG-350. The effectiveness of this reagent is currently being determined in field tests at Shenandoah Stables in Missouri.

We are also evaluating other reagents with the potential for removing chlorinated dioxins from contaminated soils.

In addition to continuing our work on contaminated soil problems, the program has expanded to encompass the development of methods or technologies for treating dilute aqueous wastes. Some of the projects currently under way include the following.

Low Pressure Composite Membranes. Recent developments in membrane construction include new non-cellulosic polymers capable of operating over a wide pH range and the use of these materials to construct composite membranes.

Systems incorporating these membranes operate at low pressures and are capable of separating both organic and metal salts at high water fluxes. Our project will evaluate concentration factors, permeate quality, and water flux for selected classes of organic priority pollutants and heavy metals. We plan to selectively separate hazardous organics and salts.

Low Cost Adsorbents. As a by-product of the paper industry, "pristine lignin" is extracted using weak caustic solutions following the delignification of wood. We are investigating this lignin as an adsorbent, weak cation exchange resin, and as a coagulant or precipitating agent. Its low cost relative to other adsorbing materials offers a high potential for this material.

PCB Sediment Decontamination Process. Solvent extraction systems for PCB recovery from sediments are being evaluated and will be used to generate performance data for the development of a full-scale recovery treatment system. This particular project is a spin-off of exploratory research conducted in our laboratory.

Supercritical Fluid Extraction of Aqueous Hazardous Wastes. We currently have two projects under way using compounds such as carbon dioxide or lower hydrocarbons as the solvent for organic compounds. These compounds have a much lower critical temperature and pressure than water and, therefore, are easier to handle. By concentrating the pollutants, other chemical reagents developed or under investigation could be used to destroy concentrated pollutants more efficiently.

Reversible Gel Absorption. Crosslinked polymer gels having the ability to absorb ten times or more their weight in water have been developed. Our project will test these compositions to concentrate aqueous wastes so that the organic portion may be incinerated or disposed of by some other means. The feature of these gels is their ease of regeneration. Absorbed water is released as the pH is lowered by about 0.5 unit or the temperature is raised about 50°C.

Plasma Torch. In conjunction with the State of New York, we are constructing and evaluating a mobile plasma pyrolysis unit with 4 kilograms per minute capacity. After tests in Kingston, Canada, the facility will be moved to a Superfund site in New York to dispose of difficult-to-treat wastes. We believe this process is cost effective and will provide an alternative for particularly difficult-to-treat wastes.

Interaction With Private Sector

Most of the work we do is done extramurally. Because of this, cooperation with private industry or non-profit groups such as universities is essential. There are three ways in which we institute activity to examine a particular technology or work with a specific company.

1. Annually, we solicit in the Commerce Business Daily (the Government newspaper) for ideas of innovative or emerging technologies for solving a particular problem. Recent solicitations were for technologies which could treat dilute aqueous wastes and technologies which could detoxify dioxin-contaminated soils. The specific subject for which we

indicate an interest is dependent upon the needs of the Agency at the time we plan the solicitation.

2. Our Regional Offices ask us to evaluate a particular technology or system that is touted as being effective for a particular problem. One of our missions is to provide this technical support to other components of the Agency. Frequently, their request is associated with their need to issue a permit to a firm that proposes to use a technology for which there is little past experience or information on its effectiveness.

3. Oftentimes, individuals or firms with ideas will approach us to cooperate with them in the evaluation of their system. There are factors, however, that must be considered before we can enter into such an agreement. One is funding. Our budget must be such that we have discretionary funds available for these activities. This is a particularly difficult choice for us because the variety of ideas or schemes do not all reach us at the same time. In the past, we found that we would make a decision on one, only to find out later that a new idea is available that would be more appropriate to fund than the one we had already chosen. Our policy now is that we will use an annual solicitation process for those cases where we had discretionary funds. If a proposer requests funding after the solicitation is closed, we would advise them to wait for the next round of solicitations. Another item that we are particularly sensitive to is that we not get ourselves in the position where we become an underwriter's laboratory, thereby checking out every technology or scheme that is presented to us. We do not have the resources to do this. This, of course, presents a problem when selecting the technologies that we do examine. For the ones we choose, the selected company obviously has a marketing advantage should the tests prove successful. Another reason then for annual solicitations is to avoid any indication of favoritism. We judge all proposals against the same criteria and, just as in any contract, select by means of a competitive process.

We do often work with companies who have a particular facility uniquely suited for the tests that we wish to conduct. That type of arrangement enables us to reduce the cost of our research in that we do not have major capital expenditures; we simply provide funds for conducting the tests at their facility. We have been very successful in working with a number of industries, e.g., with the oil shale industry in the late seventies. More recently, we have experienced excellent cooperation with the private operators of incinerators, boilers, and kilns to conduct tests for our Thermal Destruction Program. We anticipate having equal success and cooperation with firms that have waste treatment units or waste streams that must be evaluated in our existing treatment program.

Most often we deal with technologies that are beyond the proof-of-principle stage. Even in our emerging technologies programs we try to study or evaluate those technologies that have not yet been commercialized but have been brought to the point of likely success. Generally speaking, in these situations patents already exist or are pending on these processes. There is no question of patent rights as a result of our involvement. Our Agency's policy is to

encourage companies to work with us; therefore, we protect and honor their rights to patents for the technologies they develop. There are instances where we are at the front end of the development of a technology. In those cases, we have either obtained patents from our own work or have a prior arrangement with the developer that any patentable process resulting from our cooperative work will be available for use by the Government without fee.

As you can see, our hazardous waste treatment program is very comprehensive. It includes examining existing treatment methods and trying to find better technologies or more cost efficient means of treating hazardous wastes. We believe the program will provide timely alternatives to the land disposal of hazardous materials. We welcome individuals working in this field from outside the Agency to participate with us in this research. We are highly dependent upon the cooperation of industry and have had a history of success in working with them.

Thermal Destruction Research Program

The thermal destruction of hazardous waste materials is regulated by the U. S. Environmental Protection Agency. As part of the Agency's regulation development program, the Office of Research and Development provides technical support to the regulating arm of the Agency--the Office of Solid Waste. This support is provided through internal technical assistance in the development of various provisions established within the Agency's regulations. This engineering research effort has been under way for six years. Today this program's activities are focused in the Alternative Technologies Division of the Hazardous Waste Engineering Research Laboratory in Cincinnati, Ohio. Through the Division's staff and their involvement in other Agency activities, the program also influences those hazardous waste thermal destruction activities under way at the Engineering Research Laboratory at Research Triangle Park, North Carolina; the Hazardous Waste Research Center at Louisiana State University; and the research supported by the Office of Exploratory Research's Grant Assistance Programs.

Needs for Research

The research programs conducted are in support of three major activities:

(1) The development of regulations that will ensure the safe disposal of hazardous materials in thermal destruction processes;

(2) Providing guidelines for stipulating operating conditions that are necessary for proper operation of hazardous waste thermal destruction facilities; and

(3) To establish engineering relationships to monitor compliance of permitted facilities, thereby ensuring the continued proper operation of those facilities.

Current regulations are performance based, requiring 99.99% waste destruction and removal, 99% HCl control, and limits on particulates to 180 mg/dscm. They are contained in 40 CFR 264, Subpart O, Sections 264.340-264.351.

Past Research on Incinerators

The program participated in conducting a regulatory impact analysis as part of the hazardous waste incinerator regulatory development activity. This included a definition of baseline performance of incinerators operating under normal conditions and the evaluation of cost and benefits of alternative regulatory approaches. In this program, nine full-scale facilities were evaluated from 1981 through 1983. Prior to this (1974-1981), information was obtained during seven field tests on incinerators burning hazardous wastes. In our most recent tests, we established a baseline destruction and removal efficiency (DRE) that could be achieved by incinerators under normal operating conditions, examined the products of incomplete combustion (PIC's), and investigated the impacts of incinerator operating conditions such as temperature, residence time, heat input and excess air on DRE's. We also examined the impact of waste feed characteristics on DRE, the levels of hydrogen chloride and particulate emissions and how they varied with operating conditions and control systems. The effect of air pollution control systems on the emissions of principal organic hazardous constituents (POHC's), hydrogen chloride and particulates were investigated. Our program did not attempt to thoroughly document the relationship between specific incinerator designs and destruction of hazardous constituents nor did we conduct a statistically valid matrix of incinerator parameters or facility designs. We did apply rigorous quality control to our tests procedures. Table A provides a listing of the incinerators tested, the date of the tests, and where they are located. Table B provides general operating conditions or characteristics of the facilities.

Process Description and Process Data for the Tested Incinerators

Metropolitan Sewer District. The incinerator has a rotary kiln and a cyclone furnace connected to a single secondary cylindrical combustion chamber. Gases leaving the secondary combustion chamber are quenched with water and pass to a venturi scrubber for particulate removal and then through a caustic scrubber for HCl removal. The gases pass through a demister before they enter the stack.

Chemical Waste Management, Inc. The Vulcanus I Ship has two vertical liquid injection incinerators. Wastes are fed through three injection guns angled to induce cyclonic combustion. There is no particulate or HCl controls.

Ross Incineration Services, Inc. This incinerator has a large rectangular-shaped combustion chamber and a rotary kiln and has four waste feed streams. Aqueous waste fed continuously into the combustion chamber above the rotary kiln exits. Liquid organic waste is fed continuously at the opposite end well below the gas exhaust duct that is near the top of that end of the chamber. The other two waste feeds are both drummed waste. Gases exiting the combustion chamber pass through a water quench section and two packed-bed scrubbers with caustic addition to adjust pH. The gases then pass through a two-stage ionizing wet scrubber and into an induced draft fan that discharges into the stainless steel stack.

Plant B. Information not available at this time.

TABLE A

HAZARDOUS WASTE INCINERATOR FACILITIES TESTED

1981 - 1983

Incinerator	Location	Date of Test
Metropolitan Sewer District	Cincinnati, OH	7/19-26/81 9/27-10/3/81
Chemical Waste Management, Inc.	Gulf of Mexico	12/81-1/82 8/83
Ross Incineration Services, Inc.	Grafton, OH	6/10-11/82
Plant B		7/21-26/82
Upjohn Company	LaPorte, TX	8/12-13/82
Zapata Industries, Inc.	Butner, NC	9/28-30/82
American Cyanamid	Willow Island, WV	10/26-30/82
Mitchell Systems, Inc.	Spruce Pine, NC	11/3-5/82
Du Pont Pontchartrain Works	LaPlace, LA	11/17-18/82
Trade Waste Incineration, Inc.	Sauget, IL	2/2-5/83

TABLE B

CHARACTERISTICS OF THE FACILITIES

Incinerator	Average Heat Input ($x10^6$ BTU/hr)	Comb. Temp. (°F)	Average Total Residence Time (Seconds)
Metropolitan Sewer District	Kiln 52 Cyclone 62	1650-2400	1.5-3.7
Chemical Waste Management, Inc.	100	2370-2730	1
Ross Incineration Services, Inc.	74	2043-2110	6.2-6.7
Plant B	--	--	--
Upjohn Company	15	2000	3-4
Zapata Industries, Inc.	1.4	1238-1660	.063-.069
American Cyanamid	4.5	1164-1434	.17-.24
Mitchell Systems, Inc.	9.5	1800-2100	2-3
DuPont Pontchartrain Works	LII 16.4 Kiln 17.5 AB 1.2	2642 1382-1485 1773-1832	.26 6.5 0.72
Trade Waste Incineration, Inc.	10.5	1980	3.0-4.7

Upjohn Company. This incinerator consists of a small burner/ignition chamber section followed by a horizontal, cylindrical thermal oxidizer chamber. Liquid waste flow is manually controlled by adjusting storage tank pressure. The liquid waste, natural gas, and combustion/atomization air are fed to the burner assembly while hazardous waste gases are fed to the ignition chamber. Natural gas is used as an auxiliary fuel to maintain proper temperature control. Combustion gases leave the oxidizer and travel downward through a spray chamber and quench pot before entering a vertical scrubber/demister and exiting via the exhaust stack.

Zapata Industries, Inc. This incinerator has a pyrolytic chamber and a thermal reactor. All waste is fed to the incinerator from a single waste feed tank. Gases from the pyrolytic chamber pass into the thermal reactor where additional air is added. There is no control device for particulates or HCl.

American Cyanamid. This incinerator has a small chamber to mix the primary air with waste followed by the combustion chamber in which secondary air is added. Exhaust gases from the combustion chamber enter the stack. The unit is started on natural gas. The facility burns two different waste streams--an aniline waste and a mononitrobenzene waste. Aniline waste collects in a pressurized tank and is fed to the incinerator by steam pressure. The wastes are burned separately. The system does not have any emission control devices.

Mitchell Systems, Inc. The incinerator tested is a commercial facility designed primarily to burn liquid wastes but also with the capability to accept solid wastes in small quantities. The unit consists of two, horizontally-oriented, cylindrical combustion chambers (primary and secondary) situated one above the other. Two types of liquid wastes--organic and aqueous--are normally processed by the facility. They are stored and handled separately. Waste liquids are fed to the primary combustion chamber using two, air-atomized injectors. Flow rates are established by adjusting manually operated values. Combustion gases exit through a stack at one end of the secondary chamber. There is no air pollution control technology used.

DuPont Pontchartrain Works. This incinerator system has a single stage liquid injection incinerator coupled with a rotary kiln incinerator with a natural gas-fired afterburner. A liquid organic waste is fed continuously to both the liquid injection incinerator and rotary kiln from waste feed storage tanks. The rotary kiln incinerator is also intermittently fed solid waste composed of two types of coke waste, a filter cake waste, and waste paint. These solid wastes were fed to the kiln in cartons and drums. Effluents from both incinerators are combined and fed to a water quench system and a cyclone which acts to remove particulate matter and droplets entrained in the exhaust gas. After exiting the cyclones, the gas streams combine and pass through a common absorber system, very high pressure rise ID fan, and stack.

Trade Waste Incineration, Inc. This incinerator has a two-stage combustion chamber, a quench section, a Venturi scrubber and a packed scrubber. The wastes are continuously fed into the primary combustion chamber which operates in a starved air mode. Solid waste is inserted into the chamber using a manual ram. Combustion air and fuel oil are also admitted into the chamber to control the combustion temperature. The combustion gases exit the primary combustion/pyrolysis chamber and enter a secondary chamber where additional fuel oil and

combustion air are admitted to maintain desired excess air operating conditions. After leaving the second chamber, the gases are quenched and passed through a venturi scrubber for particulate and HCl removal. The gases then travel up through a mist eliminator and exit the process through the stack.

General Conclusions Available From Incinerator Tests

One key element throughout these tests was to determine the DRE's for any selected principal organic hazardous compound that was at or greater than 100 ppm. DRE's were evaluated for both volatile and semi-volatile compounds of interest. Of the 134 volatile and 106 semi-volatile data points obtained during this series of tests, the DRE's ranged as shown.

TABLE C

	DRE Range				
Type of POHC	<99	99-99.9	99.9-99.99	99.99-99.999	>99.999
Volatiles	2	12	30	51	39
Semivolatiles	3	5	20	46	32

DRE's less than 99.99 percent tend to result with low concentration of the POHC in the waste feed or from compounds commonly identified as PIC's. In the latter case, the formation of these compounds during the incineration of other chlorinated organics may have increased that compound's concentration in the stack gas resulting in the lower DRE. Extensive efforts were made during these tests to examine a variety of potential relationships between DRE and waste feed and incinerator operating parameters that had been postulated. However, due to the number of facilities tested and the variety of designs and conditions at each, no definitive, statistically sound correlations could be made.

A second consideration related to the incinerator performance was the formation of PIC's. From the results of our tests, the total mass of identified PIC's were compared to the total input POHC mass levels. On average, the PIC's were slightly higher than the residual POHC levels in the stack although this relationship varied widely from facility to facility. Most often the PIC mass output rates were less than 0.01 percent of the POHC input rate. Three explanations are considered for the presence of PIC compounds.

(a) The compounds were formed as products of combustion reactions;

(b) The compounds were introduced into the system from some source (i.e., ambient air) other than the waste; and

(c) The compounds were actually present at low concentrations in the feed and were destroyed at relatively low DRE's.

At six of the eight facilities, analyses were made for furans and dioxins exiting the stack. Concentration ranges were:

TDCF: 0.0007-0.047 ng/L
PCDF: 0.0005-0.023 ng/L
TCDD: 0.021 ng/L
PCDD: 0.001 ng/L

No 2,3,7,8-TCDD was detected.

All facilities tested reasonably well with respect to HCl emissions regulations. The data collected during these evaluations indicate that achieving a particulate emissions limitation of 180 mg/dscm (corrected to 7 percent oxygen) may be more difficult with particulate generating types of wastes than achieving either the HCl or the DRE standards for hazardous waste incinerators unless high-energy or sophisticated controls are used. Five of the nine facilities failed to meet the limit of 180 mg/dscm, and two additional facilities were marginal.

Many metals contained in the waste feed to incinerators eventually emit from the incinerator by one of three pathways--as part of the vapor or particulate emission from the stack, in liquid or solid effluents from the control device, or in the incinerator ash. Our studies confirmed that the presence of metals, especially heavy toxic metals such as mercury, lead, cadmium, chromium, and arsenic, etc., should be carefully monitored in any hazardous waste stream destined for incineration. Our testing indicated that substantial portions (i.e., up to 50 percent or more) of most metals which can vaporize at temperatures normally experienced in combustion chambers are not always condensed or otherwise trapped within the ash or air pollution control systems normally employed.

Past Research on Kilns

Industrial kilns provide a potentially attractive way to dispose of hazardous materials due to the high temperature combustion process and the large number of plants in place potentially available to handle large quantities of materials. The possibility of temperature excursions tend to be minimal due to the huge thermal inertia of these systems. To evaluate the success of these facilities for destroying hazardous wastes, we conducted a series of eight tests on kilns. The plant name, location, and other information on the facilities tested are provided in Table D.

General Conclusions Available from Kiln Tests

In general, these facilities were capable of providing 99.99 percent or greater destruction of the wastes. An exception to this was the aggregate drying kiln facility. This poorer performance is attributed to the lower operating temperature of that kiln. Particulate emissions from these facilities did not seem to significantly change when wastes were used. This pollutant is controlled by regulations under the Clean Air Act. Sulfur dioxide and hydrogen chloride increased in the recycled dust as waste load increased, but this did not significantly affect stack emission rates. No dibenzo dioxins or dibenzo furans emissions were found. Products of incomplete combustion (PIC's) emissions were, in general, less than POHC emissions. Lead and zinc emissions tended to increase as waste quantities increased.

TABLE D

CEMENT KILNS TESTED

Name	Place	Kiln Type	Size	Type of Fuel Used	Date Test Was Made	Heat Input
Lone Star Industries	Oglesby, IL	Dry Process Cement	1450 T/day	Pulverized Coal	12/83	440M BTU/hr.
Florida Solite Corporation	Green Cove Springs, FL	Aggregate	240 T/day	Crushed Coal/Waste	2/83	44M BTU/hr.
Mid Florida Mining	Lowell, FL	Aggregate	40 T/day	Waste Oils and Solvents	3/84	37.5M BTU/hr.
Carolina Solite	Aquadale, NC	Aggregate	9-10 T/day	Pulverized Coal/ Wastes	4/84	27-30M BTU/hr.
General Portland	Paulding, OH	Wet Process Cement	750 T/day	Pulverized Coal/ Wastes	10/83	180M BTU/hr.
Rockwell Lime Co.	Rockwood, WS	Lime	150 T/day	Petroleum Coke	4-5/83	50M BTU/hr.
San Juan Cement Co.	San Juan, PR	Wet Process Cement	720 T/day	Fuel Oil	10/81-2/82	212M BTU/hr.
General Portland	Lebec, CA	Dry Process Cement	2160 T/day	Coal/Petroleum Coke	8/84	450M BTU/hr.

The residence times in these facilities are on the order of seconds. The operating temperatures for the cement kilns typically ranged from 2500-3000°F, and in the lime kilns from 2100-2300°F. In the one kiln dryer, the temperature range was from 1100-1200°F.

Past Research on Boilers

Significant quantities of hazardous wastes are destroyed in industrial boilers. Our program conducted performance tests on 11 such boilers. The description of the boilers and other pertinent-facts pertaining to them are given in Table E.

A total of 42 waste fuel-fired tests were performed. At sites G and J, wastes constituted 100 percent of the fuel. Most boilers were tested at one steam load condition with the waste fuel typical of the site operating practice. Most bulk residence times were nearly 2 seconds. In 7 of the sites, waste fuels were spiked with a mixture of carbon tetrachloride/chlorobenzene/ trichloroethylene to broaden our ability to determine waste destruction efficiencies and to facilitate cross-boiler comparisons.

General Conculsions Available from Boiler Tests

Criteria Gas Emissions. Average CO, corrected to 3 percent oxygen, ranged from 18-4000 ppm, NO_x emissions ranged from 40-1100 ppm, and TUHC emissions ranged from undetectable to 160 ppm. The most common reasons for variations appeared to be insufficient fuel air mixing, unstable burner conditions leading to burner flame outs, and excess air surges.

POHC Destruction. The measured waste destruction deficiencies were in the vicinity of that required under the RCRA incinerator regulations. It is important to note, however, that during these tests the processes were not operated in a normal mode. Boiler parameters such as load and excess air rates were held constant during the tests to ensure uniform conditions for the required sampling period. For those few cases where lower DRE was noted, it seemed to be brought about by such things as improper placement of the fuel guns in the burner ports which led to nozzle clogging and probable fuel jet impingement on the burner throat. In some cases, this led to burner flameout.

PIC Emissions. Emissions of PIC's were generally one or two orders of magnitude greater than POHC emissions. It appears that the trend observed from these tests indicates the importance of not only the waste but the primary fuel combustion as possible background contamination. Uncertainty associated with low level detection of these compounds could also contribute to the presence of PIC's.

Goals of Future Work

It is important to note that three replicate sample runs were conducted to obtain data for regulatory development during tests on all three classes of facilities. Thus, during signficant upset periods, sampling probes were pulled from the stack until steady-state conditions were regained. It is obvious that this left unanswered performance characteristics during transient or upset conditions. For all three classes of facilities, the tests did show that good designs can be successfully and satisfactorily operated and meet current requirements of the regulations.

TABLE E. BOILERS TESTED

Site	Boiler Type	Steam Capacity (10^3 lb/hr)	Primary Fuel	Injection Mechanism	Typical Operation	POHC's of Interest
A	Watertube stoker	10	Wood waste	Mixed with wood	Fluctuating loads, combustion air and waste feed	Phenol, pentachlorophenol, naphthalene fluorene, 2-4-Dimethylphenol
B	Packaged firetube	8.5	Natural gas	Air atomized oil gun	Low boiler load. Maximum waste fire rate of 40 gph.	Toluene
C	Field-erected watertube	230	Natural gas or oil	One or two steam atomized burners	Low load with reduced number of burners. High excess air.	Phenol
D	Field-erected converted watertube stoker	90	No. 6 oil	One of the lower level steam atomized burners	About 50 percent capacity with 3 or 4 burners in service	Tetrachloroethylene, Bis(2-chloroethyl) ether, toluene
E	Packaged watertube	110	No. 6 oil	Two steam atomized waste guns in main burner throat	Part load with maximum 240 gph waste firing rate for loads above 50 percent	Methylmethacrylate, -hydroxy methyl isobuty-rate and -hydroxy isobutyrate methyl ether, carbon tetrachloride, chlorobenzene, trichloroethylene, toluene, and methylmethacrylate
F	Field-erected converted watertube	60	No. 6 oil, gas, or propane	Lower steam atomized oil burner	Part load with maximum 180 gph waste firing rate for loads above 50 percent	Carbon tetrachloride, chlorobenzene, trichloroethylene, toluene
G	Modified packaged firetube	40.0	None	Available air atomized oil gun	Part load with startup on natural gas. Total chlorine up to 80% of waste fuel.	Carbon tetrachloride, epichlorohydrin, bis (2-chloroisopropyl) ether
H	Field-erected tangentially-fired watertube	250	Pulverized coal	One or two steam atomized oil burners	At boiler capacity with maximum 420 gph waste firing rate	Carbon tetrachloride, chlorobenzene, 1,1,1-Trichloroethane
I	Packaged watertube	62	Natural gas	Either upper or lower steam atomized burner	Staged combustion for low NO_x with maximum 120 gph waste flow	Carbon tetrachloride, chlorobenzene, trichloroethylene, toluene, aniline, benzene, nitrobenzene
J	Packaged firetube	10	None	Available oil burner	Typical excess air of 17%	Carbon tetrachloride, chlorobenzene, trichloroethylene, toluene
K	Packaged watertube	60	No. 6 oil	Mixed with heavy oil	Typical 70/30 percent heavy and light oil mixture	Carbon tetrachloride, chlorobenzene, trichloroethylene, toluene, benzene

As a result of the information we obtained from this past research, we have established several major goals for our Thermal Destruction Program. These goals are as follows.

- To define easily monitored incinerator facility operating parameters (e.g., CO/THC ratio, CO/CO_2 ratio, etc.) which correlate with system performance (e.g., DRE, PIC formation, etc.) so as to allow rapid, real-time, reliable and economical determination by enforcement officials of compliance with permit conditions and to define the necessary preventive or corrective actions to avoid uncontrolled excursions from permit conditions. This research will examine transient conditions (start-up, shut-down, waste composition anomalies, power failures) which can throw facilities into a failure mode with respect to permit conditions.

- To provide the necessary scientific basis for selecting the appropriate POHC's for specification in permits and for delineating those conditions of operation required to prevent the formation of hazardous PIC's.

- To further the assessment of the performance capabilities of existing or proposed hazardous waste thermal destruction devices thereby providing envelopes of operating conditions within which failure of the device is avoided. This will provide the technical basis for conditions in Agency-issued permits.

- To develop an adequate understanding of thermal destruction chemistry and the engineering of thermal processes so as to be able to characterize and assess the performance of full-scale thermal destruction devices from a minimum set of evaluative tests and extrapolate performance information from one waste type to another or from one scale or type of equipment to another. This hard-to-achieve goal could some day reduce the time/expense for obtaining a permit.

Currently Planned Research

The Hazardous Waste Thermal Destruction Research Program is conducting three groups of research toward reaching the above-stated goals: (1) work in-house at our Center Hill Facility in Cincinnati, Ohio, and at the Combustion Research Facility in Jefferson, Arkansas; (2) a series of evaluations at full-scale facilities to evaluate performance during transient conditions for the three classes of equipment; and (3) conduct additional full-scale tests at facilities to verify the hypotheses that evolve from our in-house research. We also have conducted and will continue to conduct evaluations of innovative and emerging thermal processes for the destruction of hazardous wastes.

At the Center Hill Facility, the research employs a small flat-flame burner, a 4-inch diameter turbulent flame reactor, a 15-inch diameter control temperature tower, and a unit for determining decomposition profiles in a non-flame environment. At the Combustion Research Facility, we employ two pilot-scale facilities in our research--a rotary kiln with an afterburner and a liquid injection incinerator. The nominal size of each of these units is 3 million BTU's per hour. The units are highly instrumented and are provided with redundant air pollution control equipment that enables us to

operate these facilities in a failure mode without adversely impacting the environment. This facility has a Part B RCRA permit. We currently plan to conduct non-steady-state tests at a variety of cooperating facilities.

Innovative technologies that we have evaluated to date are a plasma arc unit, a high temperature electric furnace, a molten salt reactor, a supercritical water destruction process, and a catalytic wet oxidation system.

The information from each of these research efforts is analyzed and interpreted within our engineering analysis program. In this program, we examine the data from a variety of scales, waste streams, facility types, and operating conditions in an attempt to derive the necessary data or models that will enable us to define the engineering relationships that are necessary to develop a compliance strategy for the Agency and to establish operating conditions within the permits that are issued for thermal destruction facilities.

Funding History

The attached chart depicts the resources we have applied to our Thermal Destruction Program during the last 6 years.

Coordination With Outside Groups

As mentioned earlier in this paper, we make a concerted effort to coordinate our activities with other groups that are receiving funds from the Agency for thermal destruction research. In addition to that, we have established a Technical Working Panel, which is comprised of 5 individuals outside of EPA who are recognized national experts on thermal destruction of waste materials. Those individuals meet with us periodically to review the technical aspects of the information obtained from our research. That Panel will revolve membership periodically. We have found this to be a useful way to supplement the periodic Agency peer reviews that are conducted on this program.

We encourage anyone who has an interest in thermal destruction research to contact us with their ideas or to volunteer to become associated with our programs. We welcome individuals working in this field from outside the Agency to participate with us in this research which we believe is destined to provide a viable alternative for the destruction of hazardous materials in the United States.

FUNDING HISTORY